University of California, Berkeley
Physics H7A Fall 1998 (*Strovink*)

PROBLEM SET 5

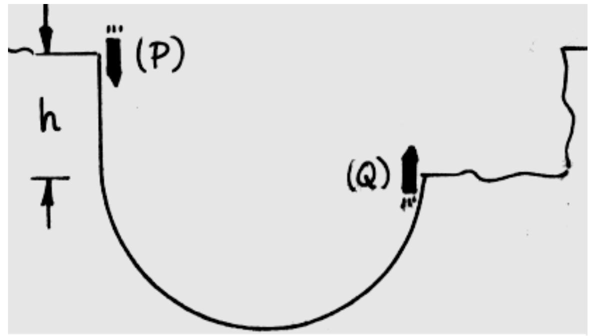
1. Mass M rests on a table, and mass m is supported above it by a massless spring which connects the two masses.

(a.) Find the minimum downward force that must be exerted on m such that the entire assembly will barely leave the table when this force is suddenly removed.

(b.) Consider this problem in the time-reversed situation: Let the assembly be supported above the table by supports attached to m. Lower the system until M barely touches the table and then release the supports. How far will m drop before coming to a stop? Does knowledge of this distance help you solve the original problem?

(c.) Now that you have the answer, check it against your intuition by (1) letting M be zero and (2) letting m be zero. Especially in the second case, does the theoretical result agree with your common sense? If not, discuss possible sources of error.

2. It has been claimed that a rocket would rise to a greater height if, instead of being ignited at ground level (P), it were ignited at a lower level (Q) after it had been allowed to slide from rest along a frictionless chute – see the figure. To analyze this claim, consider a simplified model in which the body of the rocket is represented by a mass M, the fuel is represented by a mass m, and the chemical energy released in the burning of the fuel is represented by a compressed spring between M and m which stores a definite amount of potential energy, U, sufficient to eject m. (This corresponds to instantaneous burning and ejection of all the fuel – *i.e.* an explosion.) Then proceed as follows:



(a.) Assuming a value of g independent of height, calculate how high the rocket would rise if fired directly upward from rest at (P).

(b.) Let (Q) be a distance h vertically lower than (P), and suppose that the rocket is fired at (Q) after sliding down the frictionless chute. What is the velocity of the rocket at (Q) just before the spring is released? Just after the spring is released?

(c.) To what height above (P) will the rocket rise now? Is this higher than the earlier case? By how much?

(d.) Remembering energy conservation, can you answer a skeptic who claims that someone has been cheated of some energy?

3. K&K problem 4.7 "A ring of mass M hangs...".

4. Assume the moon to be a sphere of uniform density with radius 1740 km and mass 7.3×10^{22} kg. Imagine that a straight smooth tunnel is bored though the moon so as to connect *any* two points on its surface. The gravitational force on an object by a uniform sphere is equal to the force that would be exerted by the fraction of the sphere's mass which lies at *smaller* radius than the object, as if that fraction were concentrated at the center of the sphere.

(a.) Show that the motion of objects along this tunnel under the action of gravity would be simple harmonic (neglect friction with the walls of the tunnel).

(b.) Calculate the period of oscillation.

(c.) Compare this with the period of a satellite travelling around the moon in a circular orbit at the moon's surface.

5. K&K problem 4.23 "A small ball of mass m is placed on top...".

6. In an historic piece of research, James Chadwick in 1932 obtained a value for the mass of the neutron by studying elastic collisions of fast neutrons with nuclei of hydrogen and nitrogen. He found that the maximum recoil velocity of hydrogen nuclei (initially stationary) was 3.3×10^7 m/sec, and that the maximum recoil velocity of nitrogen-14 nuclei was 4.7×10^6 m/sec with an uncertainty on the latter of $\pm10\%$. What does this tell you about:

(a.) The mass of the neutron (in amu)?

(b.) The initial velocity of the neutrons used?

(Take the uncertainty of the nitrogen measurement into account. Take the mass of a hydrogen nucleus as 1 amu and the mass of a nitrogen-14 nucleus as 14 amu.)

7. K&K problem 4.13 "A commonly used potential energy function...".